European Research to support Long-term Operation of Nuclear Power Plants

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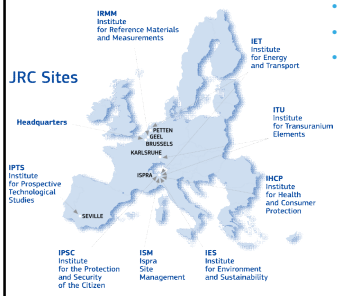
Joint Research Centre
the European Commission's
in-house science service

ec.europa.eu/jrc

JRC - Role & Facts

In-house science service *of the European Commission*



- ***Established 1957***
- ***7 institutes*** *at 6 locations*
- ***Around 3000 staff***

Institutes with Nuclear Activities:

- **IET**: Nuclear Reactor Safety
- **ITU**: Nuclear Fuels, waste, safeguards & security
- **IRMM**: Reference nuclear data and measurement standards

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Nuclear Reactor Safety Activities of JRC

NPP events (Operating Experience)	**Nuclear Safety Legislation** (EURATOM Treaty, EC Directives)	**Knowledge Management, Education and Training, Transparency**
		Support to EC Instruments (INSC, IPA)
NPP accidents (Emergency Preparedness and Response)	**Safe Long Term Operation** (Materials & components)	**European & International Standardization**

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Materials related safety issues for present and future reactors, in close cooperation with

NUGENIA NUclear GENeration II & III Association

SNETP Sustainable Nuclear Energy Technology Platform

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NUGENIA NUclear GENeration II & III Association

- International non-profit organisation under Belgian law to promote R&D on Gen II & III Reactors;
- Legally established in November 2011 & launched in March 2012;
- 103 full + 7 honorary member organisations (status Feb. 2016) with major European utilities, TSOs, vendors, research institutes, universities among them;
- Incorporates activities of 4 previous networks / TWGs

SARnet

SNETP Sustainable Nuclear Energy Technology Platform

TWG Gen II&III Reactors

NULIFE

ENIQ European Network for Inspection and Qualification

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Technical Areas:

- TA1 Plant Safety & Risk (UJV),
- TA2 Severe Accidents (IRSN),
- TA3 Improved Reactor Operation (CEZ),
- TA4 Integrity & Ageing of Systems, Structures and Components (Areva-G),
- TA5 Fuel Development, Waste & Spent Fuel Management and Decommissioning (NNL),
- TA6 Innovative LWR Designs & Technologies (Areva-F)
- TA7 Harmonisation (?)
- TA8 In-Service Inspection and Qualification (ENIQ) (EDF)

www.nugenia.org

6 Leader of each TA indicated in ()

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RPV Embrittlement & Degradation of Reactor Internals

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The SOTERIA Project

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Facts:

- 24 partner organisations: CEA (leader), EDF, Areva, AMEC FW, UJV, CIEMAT, Tecnatom, IRSN, JRC, JSI, Vattenfall, VTT, …),
- Budget: 13.9 Mio. Euro (EC contribution: ca. 5 Mio. Euro),
- Duration: 4 years (Sep 2015 – Aug 2019),
- Follow-up of FP7 projects and LONGLIFE[1] (experimentally orientated project on long-term effects of irradiation) and PERFORM60[2] (multi-scale modelling of irradiation degradation).

[1)] NUGENIA Position Paper on RPV embrittlement based on outcomes of LONGLIFE available on NUGENIA website (www.nugenia.org under "Library" → Technical reports).

[2)] NUGENIA Position Paper on multi-scale modelling of irradiation degradation based on outcomes of PERFORM60 still in draft.

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The SOTERIA Project (2)

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Objectives:

- Carry out experiments aiming to explore flux & fluence effects on RPVs & Internals of PWRs,
- Assessment of residual lifetime of RPVs taking into account metallurgical heterogeneities,
- Assessment of effects of the chemical and radiation environment on cracking of internals (IASCC),
- Development of Models for the assessment of ageing mechanisms in RPVs and internals and setup of a platform for modelling tools.

Website available soon!!

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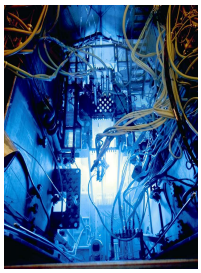
The Lyra-10 Project

Joint JRC–NRG irradiation project to investigate interaction between Ni and Mn for low Cu-content RPV steels at high fluence.

- Identify role of Ni, Mn & Cr on irradiation damage of RPV steels at high fluence and search for late-blooming phases.
- **12 batches** of model steels resembling VVER-1000 & PWR RPV steels with varying Ni, Mn, Cr contents + **8 batches** submerged arc weld steels resembling VVER-1000 RPV weld steels with varying Ni & Mn contents.
- Variations in Ni & Mn content cover typical content range found in PWR and VVER RPV steels.
- Charpy, half-size Charpy, tensile, positron annihilation, …
- Target fluence: 6×10^{19} cm^{-2} (≡ 60-80 years of reactor operation)
- Irradiation finish Q1 2017, afterwards PIE project planned within NUGENIA



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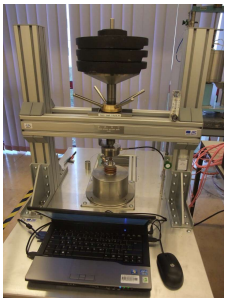
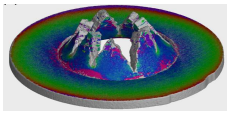
Small Punch Test

Material Characterisation test that requires only small amount of material (advantage, when material amount limited, e.g. samples from surveillance programs, new alloys for Gen IV reactors).



- Part of JRC's normalization activities
- JRC has initiated promotion of CEN CWA-15627:2007 on small punch tests into an EN standard.
- Work Item accepted in ECISS TC 101; Working group to be formed soon.



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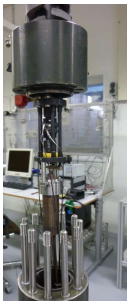
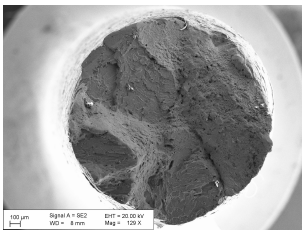
Corrosion & Stress Corrosion Cracking (SCC)





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The MICRIN Project

Tapered tensile specimens

Objectives:

- Development & application of accelerated test method for SCC initiation for common corrosion systems in LWRs (316L & Alloy 182 in BWR & PWR conditions).
- Determination of stress thresholds for SCC initiation as function of surface conditions, temperatures, strain hardening (cold work), water impurities.
- Goal of project to issue draft proposal for implementation of findings in codes & standards.

11 Partner organisations: SCK-CEN, Areva-G, CIEMAT, CVREZ, Imperial College, JRC, PSI, Raten-ICN, Univ. Manchester, VTT, ZAG

Approach: Testing organised as round robin exercise for 3 different strain rates at 2 different temperatures each (300°C and 340°C) in PWR conditions (one lab tests at 288°C in BWR conditions).

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The ASATAR Project

Topic: Development & analysis of suitability of accelerated test methods for assessing long-term reliability of nuclear components against environmentally assisted cracking (EAC).

Acceleration factor: $\eta = \frac{time\ to\ crack\ initiation\ in\ operation}{time\ to\ crack\ initiation\ in\ laboratory} = \eta_T \times \eta_\varepsilon \times \eta_\sigma \times \eta_{Env}$

- For SSC initiation test some sort of acceleration (by adjusting temperature, strain level, etc.) is required to achieve SSC initiation in reasonable time.
- Fracture mode should not change while accelerating test!!

Main Objectives:

- Prepare & analyse EAC data for future development of new procedure for estimating the long-term reliability of nuclear components.
- Analyse suitability of accelerated tests with high total accelerating factor for evaluating the time to SCC initiation.

5 Partner organisations: CVREZ (leader), CIEMAT, Imperial College, STUBA

Duration: April 2015 – September 2016

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The McSCAMP Project

Topic: Minimising nuclear component SCC through advanced machining parameters.

Objectives & Tasks:

- Identify key machining parameters influencing residual stresses,
- Identify available advanced machining techniques such as dry machining and the use of cryogenic cooling,
- Conduct a design of experiments to determine which parameters to be tested,
- Conduct machine parameter testing on coupons and on target component,
- Inspect surface and below surface material responses through various evaluation techniques (e.g. optical 3D profiling, SEM and X-ray diffraction),
- Provide recommendations for further work to identify optimum machining parameters for improving surface integrity.

3 Partner organisations: NAMRC (leader), Areva, Estoninan Univ. Life Sciences

Duration: April 2015 – September 2016

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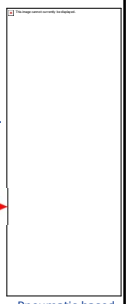
Additional SCC & Corrosion related Research by JRC

- SCC Crack Growth Rate (CGR) Tests – evaluation of acceleration of CGRs due to exposure to SCW compared to LWR conditions.
- Development & evaluation of sensors to monitor crack growth (electrochemical potential (ECP), Linear Variable Differential Transducer (LVDT)) for wide temperature range & environments. (incl. SCW).

Development of loading devices for autoclaves



Pneumatic based loading devices

Cone – Mandrel Test for testing of fuel cladding

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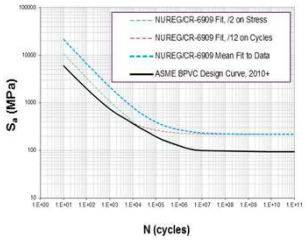
Environmental Assisted Fatigue and Very High Cycle Fatigue



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INCEFA+ HORIZON 2020

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Background: US NRC & ASME guidance for environmentally-assisted fatigue (EAF) assessment can result in calculated high fatigue usage factors that are inconsistent with plant experience.

Objectives:

- Identify most significant differences between conditions producing EAF damage in plant and laboratory tests.
- Test representative materials to improve understanding of sensitivity to these differences on fatigue life in PWR primary environment.
- Develop new procedure for assessing fatigue degradation in reactor coolant under plant conditions to avoid excessive conservatism inherent in current US NRC guidelines and draft ASME Code Cases.

- **16 partner organisations**: AMEC FW (leader), Areva-F/-G, CIEMAT, CEA, EDF, EON, VTT, JRC, SCK-CEN, UJV, PSI, Univ. Cantabria, Rolls Royce, …
- **Budget**: 6.1 Mio Euro (EC contribution: 2.55 Mio Euro)
- **Duration**: 5 years (July 2015 – June 2020)

http://incefaplus.unican.es/

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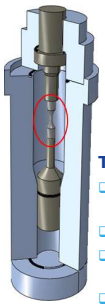
High Cycle Fatigue Testing



Motivation:

- Fatigue data normally only available for up to 10^6-10^7 cycles, but in some cases a significantly higher number of cycles can be reached, e.g. thermal fatigue in T mixing areas.
- So need for very-high-cycle fatigue (VHCF) data and data needs to be generated in reasonable time.

Test rig for VHCF designed by JRC:

- Ultrasonic excitation at 20 kHz generated via piezoelectric element;
- 10^{10} cycles in 6 days;
- Requires hourglass shaped specimen of ~60-120 mm length;
- Recent tests for Ni based Alloy Inconel 718

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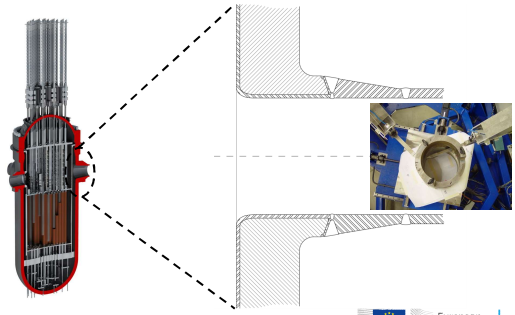
Residual Stress (RS) Measurements of DMWs with Neutron Diffraction



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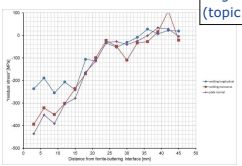
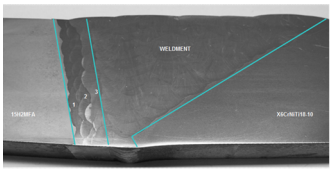
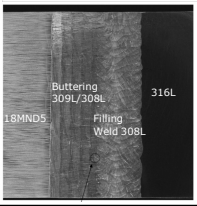
RS Measurements on DMW Mock-ups (MU)

Ongoing task of past FP7 Euratom project MULTIMETAL (topic: integrity & fracture testing of DMWs)





MU3 resembles RPV nozzle weld of VVER-440 reactor



MU2 resembles pressurizer–primary piping weld of French PWRs

Activity includes comparison with numerical RS values kindly provided by BZN, Hungary (for MU3) and Areva-F (for MU2)

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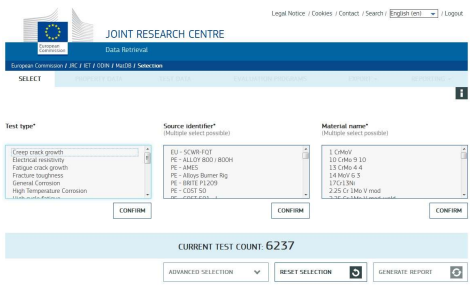
Databases



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JRC Database MatDB

Contains mechanical properties of alloys, mainly nuclear materials of Gen I-IV reactors and experimental data from European research projects.

Features:

- Hosted at https://odin.jrc.ec.europa.eu , supports online data entry, data browsing (with graphical views), data evaluation & data retrieval;
- Supports 3 access levels: Open, registered and restricted;
- Enabled for data citation, thereby allowing data sets to be cited in exactly same way as traditional scientific publications (without affecting the access level);
- Enabled for technologies developed in scope of a series of CEN Workshops on standards for engineering materials data.

Content (selection):

- MATTER (past Euratom project): ~270 data sets for various tests on 316L & P91;
- NESC I/IV (past Euratom project): ~300 data sets for fracture toughness, impact, and uniaxial tensile tests performed on A508, A533B, 308L and 309L;
- IAEA Surveillance Database: ~40.000 data sets (restricted access at moment);
- German HTR Programme: ~10.000 data sets for various tests on Alloy 800, Alloy 800H, Alloy 617, and others.

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The AGE60+ Project

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Background:

- Nuclear organisations acquired data related to ageing-induced degradation of NPPs structures / components for many years (not all published and if published publications widely dispersed).
- Individual groups must develop understanding of factors contributing to degradation, derive trend curves, build models, based on limited, **locally-available** data.

Aims:

- Encourage European researchers to share data in order to maximise its utilisation;
- Consolidate available data in readily-accessible formats;
- Expand & use existing databases to develop common understanding of trends in degradation, improve prediction of material & component behavior for extended operation / storage / waste disposal;
- Use improved understanding to assess the applicability of current degradation management methodologies to 60 years reactor operation and beyond.

5 Partner organisations: NNL (leader), UJV, MTA EK, Areva-G, CIEMAT

Duration: April 2015 – September 2016

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Codes & Standards: CEN Workshop 64 Phase 2

Aim: Provide recommendations on further evolution of French nuclear codes & standards (RCC-M, RCC-MRx, …) and required underlying research.

- **Duration**: July 2014 – June 2017;
- **Work Structure (Prospective Groups)**:
  - **PG1 Mechanical Components of Gen II & III Reactors (scope: RCC-M),**
  - **PG2 Mechanical Components of Gen IV Reactors (scope: RCC-MRx),**
  - **PG3 Civil Structures (scope: RCC-CW)**
- **PG1 Contributors**: IRSN (leader), AFCEN (Areva), AMEC FW, JRC, STUK, Tractebel, Vattenfall, VGB (= German utilities);
- **Achievements & on-going Tasks PG1**: Currently preparation of list of degradation mechanisms with prioritisation with regards to LTO impact and impact on plant safety & availability, thereby utilisation of a.o. US GALL, NUREG CR-6923, NUREG CR-7153

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National R&D Programs of EU Member States to support LTO

- **France**: Research of the Materials Ageing Institute (The MAI) (www.themai.org/en/research-project.html)
- **Czech Republic**: SUSEN Program (http://susen2020.cz/en)
- **Finland**: SAFIR2018 (http://safir2018.vtt.fi)
- …

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Many Thanks for your Attention

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